Optimizing growth by anion nutrition

Prof dr Leo Marcelis and Wim Voogt

[1]Head of chair group Horticulture & Product Physiology
Wageningen University, The Netherlands. Leo.Marcelis@wur.nl

[2]Wageningen UR Greenhouse Horticulture. Wim.Voogt@wur.nl

Content

- Growth in relation to nitrate
- Growth in relation to phosphate
- Growth in relation to sulphate
- Conclusions

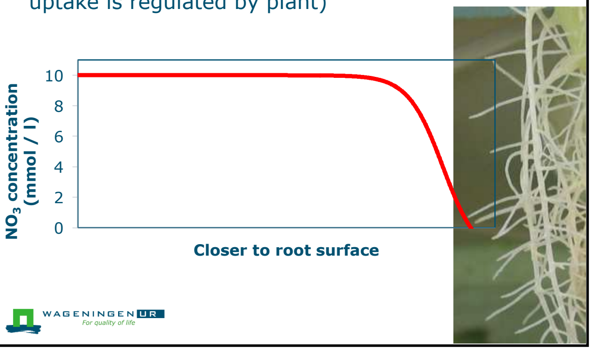
Growth in relation to nitrate (NO_3)

Functions of N in the plant

- Most essential element
  (high concentrations; 3-5% of dry mass)
- Enzymes
- DNA
- Chlorophyll → green
- Osmotic activity → water uptake

Uptake of N in the plant

- Active uptake (as long as some NO_3 at root surface, uptake is regulated by plant)

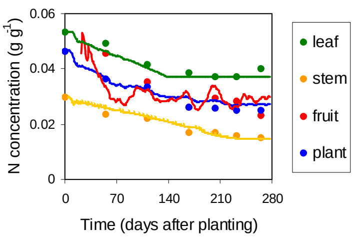


Uptake of N in the plant

- As long as N at root surface: uptake follows growth
  - Uptake depends on growth and plant concentration

Uptake of N in the plant

- As long as N at root surface: uptake follows growth
  - Uptake depends on growth and plant concentration
  - Upt= c_{leaf}*$Mass_{leaf}$ + c_{stem}*$Mass_{stem}$ + c_{fruit}*$Mass_{fruit}$ +c_r*$Mass_r$



From: Marcelis et al, 2005. Acta Hort. 691

Uptake of N in the plant

- Active uptake
- When some N at root surface: uptake follows growth
- Root uptake of NH_4 has priority above NO_3 (but much NH_4 not always good for plant)
- Mobile in plant

N deficiency

N deficiency

N deficiency

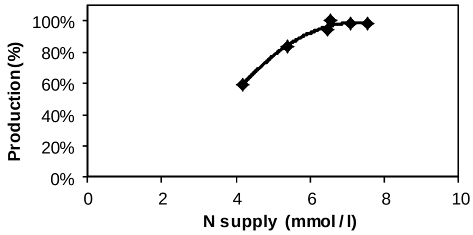
N deficiency

N deficiency

WAGENINGEN UR For quality of life

N supply

NO$_3$ supply varied, by replacing with Cl.
Closed recirculation system

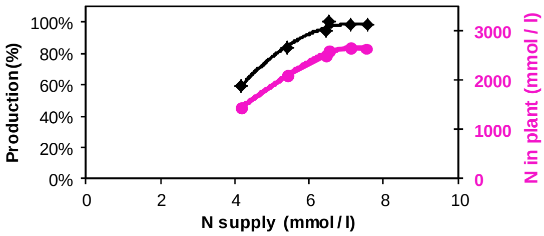


WAGENINGEN UR For quality of life

From: Voogt and Sonneveld, 2004. Acta Hort. 644

N supply

NO$_3$ supply varied, by replacing with Cl.
Closed recirculation system

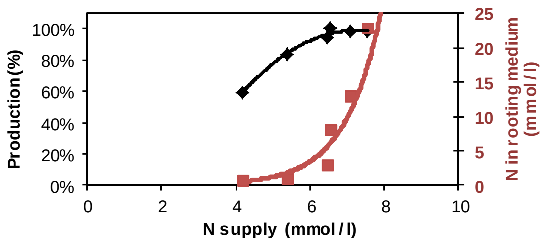


WAGENINGEN UR For quality of life

From: Voogt and Sonneveld, 2004. Acta Hort. 644

N supply

NO$_3$ supply varied, by replacing with Cl.
Closed recirculation system



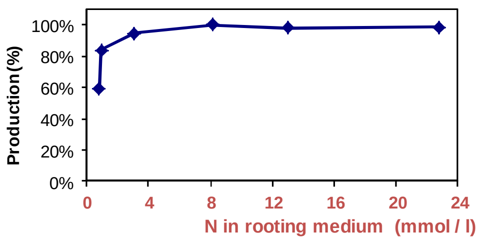
WAGENINGEN UR For quality of life

From: Voogt and Sonneveld, 2004. Acta Hort. 644

N supply

NO_3 supply varied, by replacing with Cl.

Closed recirculation system

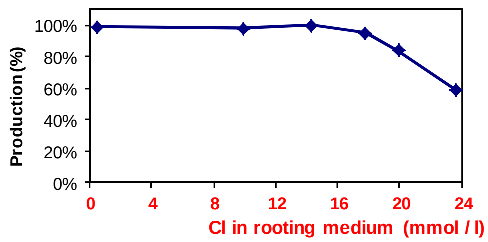


From: Voogt and Sonneveld, 2004. Acta Hort. 644

N supply – Cl supply

NO_3 supply varied, by replacing with Cl.

Closed recirculation system

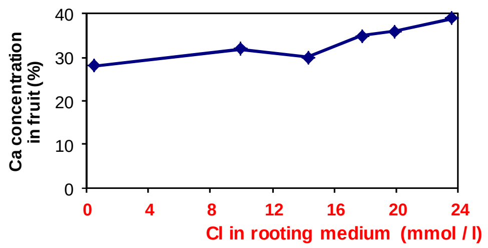


From: Voogt and Sonneveld, 2004. Acta Hort. 644

N supply – Cl supply

NO_3 supply varied, by replacing with Cl.

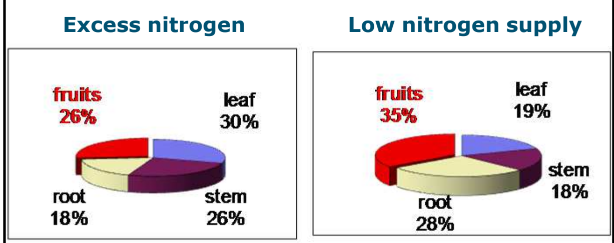
Closed recirculation system



From: Voogt and Sonneveld, 2004. Acta Hort. 644

N → Vegetative growth (tomato)

Relatively less fruits, but not less kg



From: Marcelis & Veen, unpublised

Growth in relation to phosphate (PO_4)

Function of phosphate in plant (PO_4)

- Energy metabolism (ATP, ADP)
- Cell membrane
- DNA
- Proteins
- Phosphate in seed important for seedling

Function of phosphate in plant (PO_4)

- Mobile in plant
- Low concentration in plant
- P-toxicity is rare: induced Fe, Zn deficiency

P deficiency

Low P **High P**

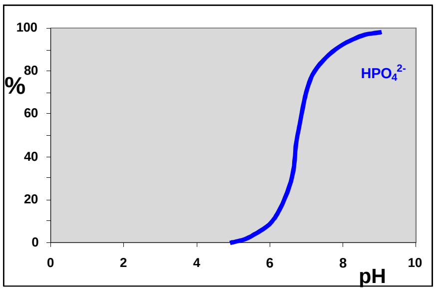
P deficiency

P deficiency

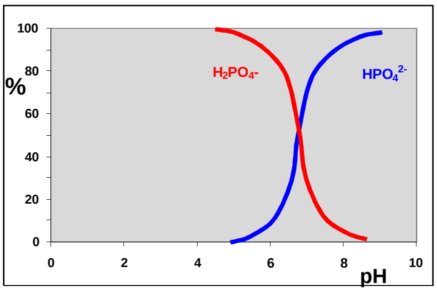
P deficiency

Low P High P

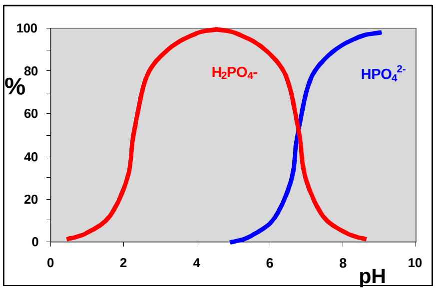
pH and phosphate availability



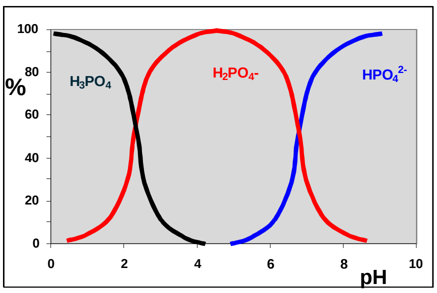
pH and phosphate availability



pH and phosphate availability

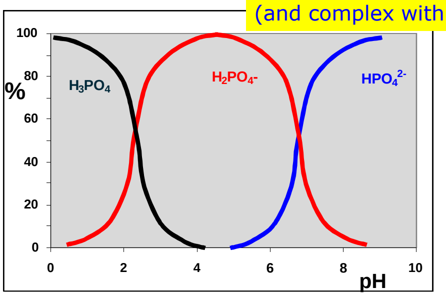


pH and phosphate availability

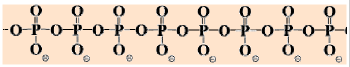


pH and phosphate availability

HPO_4^{2-} plus Ca^{2+} →
precipitation ($CaHPO_4$)
(and complex with Fe, Al)



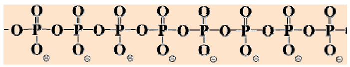
Polyphosphate



- Polyphosphate: chain of phosphate molecules
- At root: broken down in phosphates
- Root uptake: only phosphates

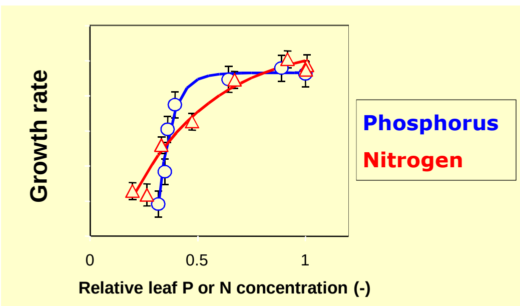
- Insensitive to pH
- Reduce precipitation and blocking of irrigation system

Polyphosphate



Most advantages when:
- High pH
- Weak roots
- Blocking of irrigation system

Growth response to concentration of P or N in plant



From: De Groot, Marcelis et al. Plant & Soil 248: 257-268

Which physiological process is reduced by phosphorus limitation?

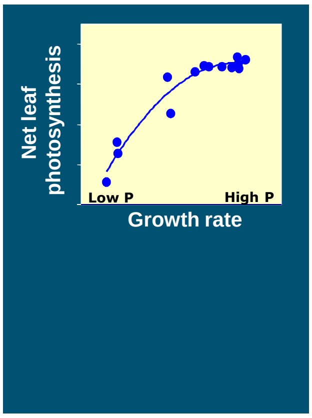
Growth = Leaf photosynthesis * leaf area

Note: I use here a simplification of:

RGR = NAR * LAR

P limitation

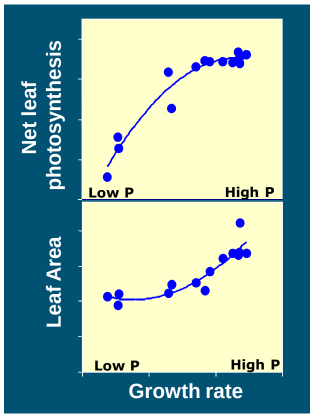
- Photosynthesis drops at **severe** limitation



From: De Groot, Marcelis et al. 2001(PCE), 2002 (FPB)

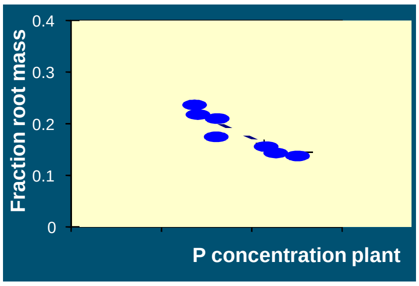
P limitation

- Photosynthesis drops at **severe** limitation
- Leaf area drops at **mild** limitation



From: De Groot, Marcelis et al. 2001(PCE), 2002 (FPB)

P limitation --> relatively more assimilates to roots



From: De Groot, Marcelis et al. 2001. PCE 24: 1309-1317

Main effects of P limitation on growth

Mild limitation:
---> less leaf area

Severe limitation:
---> less photosynthesis/respiration

Mild – severe limitation:
---> relatively more roots

Main effects of P limitation on growth

Mild limitation:
---> less leaf area

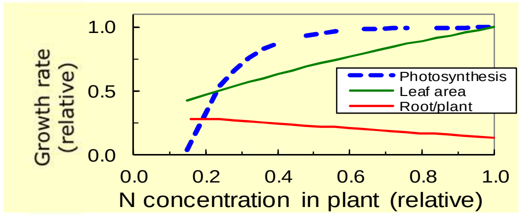
Severe limitation:
---> less photosynthesis/respiration

Mild – severe limitation:
---> relatively more roots

Same holds for Nitrogen limitation

Effects of N limitation

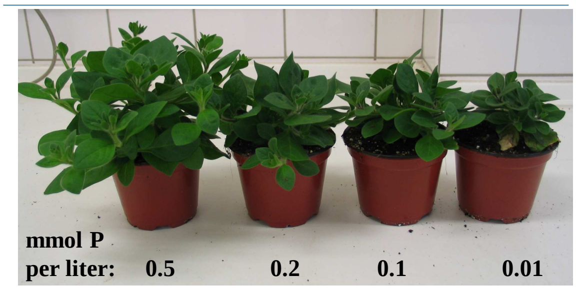
- Less leaf area,
- More roots,
- Small reduction of photosynthesis



From: Elings, Marcelis et al. Acta Hort 654

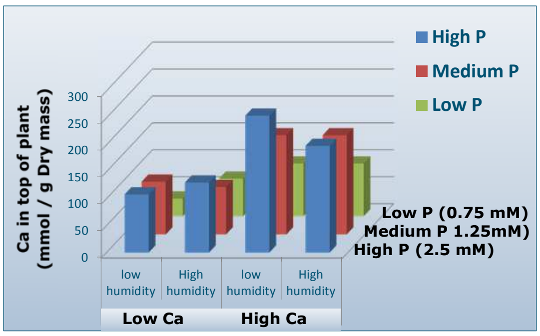
Can we use P limitation to keep plants compact?

Yes, possible, but very difficult



From: Van Noort, WUR Greenhouse Hortic, Netherlands
Baas et al. Acta Hort. 378

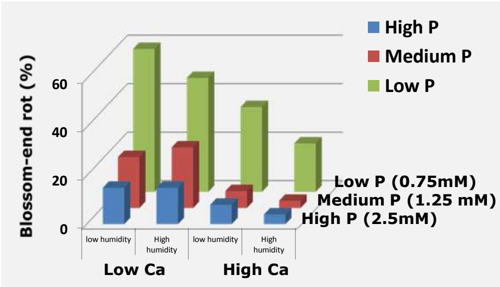
P may stimulate Ca uptake



From: De Kreij, J. Plant Nutr. 19

P may stimulate Ca uptake

Hence reduces physiological disorders such as Blossom-end rot



From: De Kreij, J. Plant Nutr. 19

Growth in relation to Sulphate (SO4)

Sulphur (S)

- Uptake as SO_4 (sulphate)
- Proteins
- Immobile in plant
- Deficiency: pale green/grey color, yellow older leaves

S deficiency

high S low S

S deficiency

high S   low S

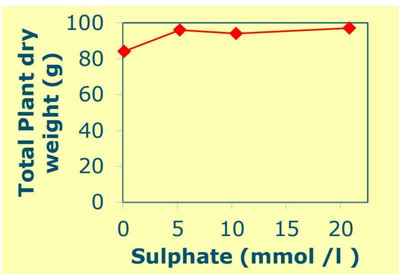
S and resistance against diseases

- S vapour → control of diseases, e.g. mildew
- S shortage roots → might lead to less resistance (this situation does usually not occur in horticulture)

SO_4 (tomato on rockwool)

Wide range no effect on growth

0.1 mmol SO_4/l → growth reduction

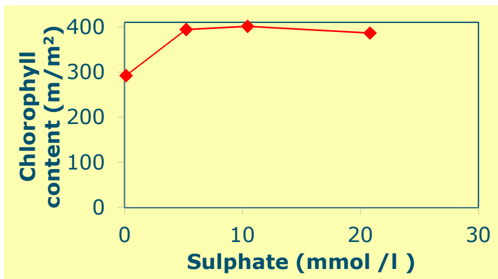


From: Lopez, Voogt, et al., Sci. Hort 67

SO_4 (tomato on rockwool)

Wide range no effect on growth

0.1 mmol SO_4/l → less green



From: Lopez, Voogt, et al., Sci. Hort 67

Conclusion

- NO_3 and PO_4: some reduction in supply no problem
  - Leaf area (vegetative growth) first to reduce
- Cl and PO_4: may enhance Ca uptake
- PO_4 availability: strongly dependent on pH
- SO_4: within wide range no effect

Questions?